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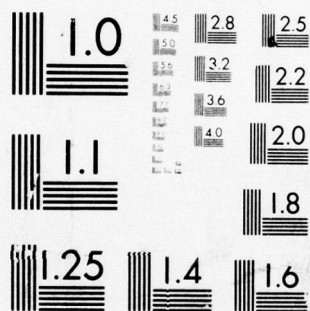
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STRUCTURAL EXCAVATION USING MOUNDING CHARGES, by C. C. McAneny, *Explosive Excavation Research Laboratory*

Project LOST CREEK was conducted by the Waterways Experiment Station's Explosive Excavation Research Laboratory (EERL) in 1972 to investigate the feasibility of using mounding charges (large, deeply buried charges) to excavate a through cut in rock—such as, for instance, a spillway. It was desired to determine whether such a departure from conventional techniques, assisted by controlled blasting, could produce stable side slopes with a minimum of damage to the rock in the walls.

A series of experimental blasts was carried out to test EERL's concepts of using "mounding" charges for rock excavation, culminating in an experiment designated the "ML" Series (for Multiple Lift). In this final experiment, a 30-ft-deep prototype spillway was excavated in two lifts.

Project LOST CREEK was performed in Jackson County, Oregon, at the quarry site for the LOST CREEK rock-fill dam being built by the U. S. Army Engineer District, Portland. The site material is a fine-grained igneous rock commonly called a basalt, but which classified petrographically as an andesite on the basis of its mineralogy. The rock is fairly uniform with extensive, irregular, closely spaced fracturing. The fractures are not open, and boreholes in fresh rock tend to be watertight. On being drilled, however, the rock parts along the fractures, so that NX cores are seldom recovered in lengths exceeding 1-1/2 ft.

The mounding technique is an approach to blasting intermediate in concept between conventional blasting and cratering. A production blast in conventional blasting is composed of a large number of relatively small-diameter blast holes, whereas in cratering a few very large explosive charges are detonated below the ground surface. A cratering blast breaks the overlying rock and also ejects it to form a crater. The mounding concept uses a few relatively large charges, similar to cratering charges, but the charges are

buried so deeply that the rock is not ejected, but only forms a mound of rubble. The rubble is then removed by conventional hauling methods. The concept of using mounding charges to excavate rock is being studied because it may offer significant savings in drilling and blasting costs in comparison with conventional blasting.

In preliminary experiments at LOST CREEK, three different blasting agents were tested in mounding detonations. ANFO proved to be markedly more effective than two different slurry blasting agents. Because ANFO is also the cheapest of the three agents and showed itself the most reliable in detonating, it was selected for use in the ML experiment.

Fig. 1 shows in plan view the design of the first lift of the ML excavation. Fig. 2 is an end-on view showing the design and results of both lifts. The final excavation appeared as shown in fig. 3.

In designing the mounding blasts, the in-row spacing for the ANFO charges was selected on the basis of prior mounding tests, performed both at the LOST CREEK Site and at another EERL test area in Colorado. The between-row spacing was based on the geometry of the pits excavated after prior mounding experiments at LOST CREEK. Had the rows been placed too far apart, too great a hump of unbroken rock would have been left between them; had they been placed too close together, broken rock between the rows would have caused difficulties in drilling of the holes for the second lift. The interval selected proved to be satisfactory.

The design of the ML experiment incorporated "buffer zones" along both sides of both lifts. A buffer zone consists of an array of small-diameter, loaded and fully stemmed blastholes, the detonation of which creates a zone of fractured rock between the main charges and the presplit surface. The buffer zone is designed to protect the presplit surface by attenuating the shock from the main charges and by offering an avenue of escape for explosion gases.

The presplit spacings on the first lift, and those of the buffer zones, were designed on the basis of test panels.

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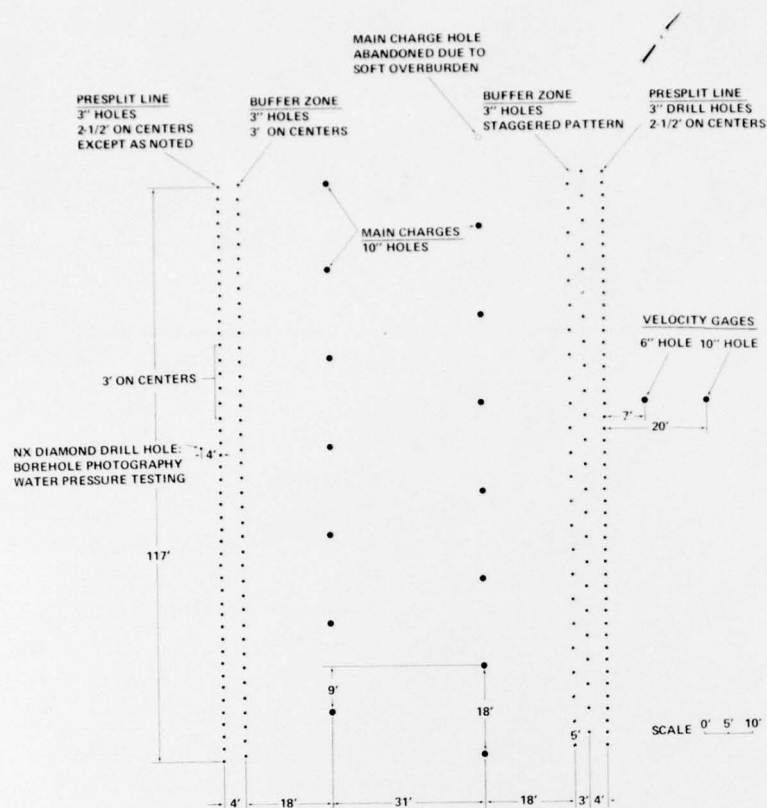


Fig. 1. Plan View, ML-1 design

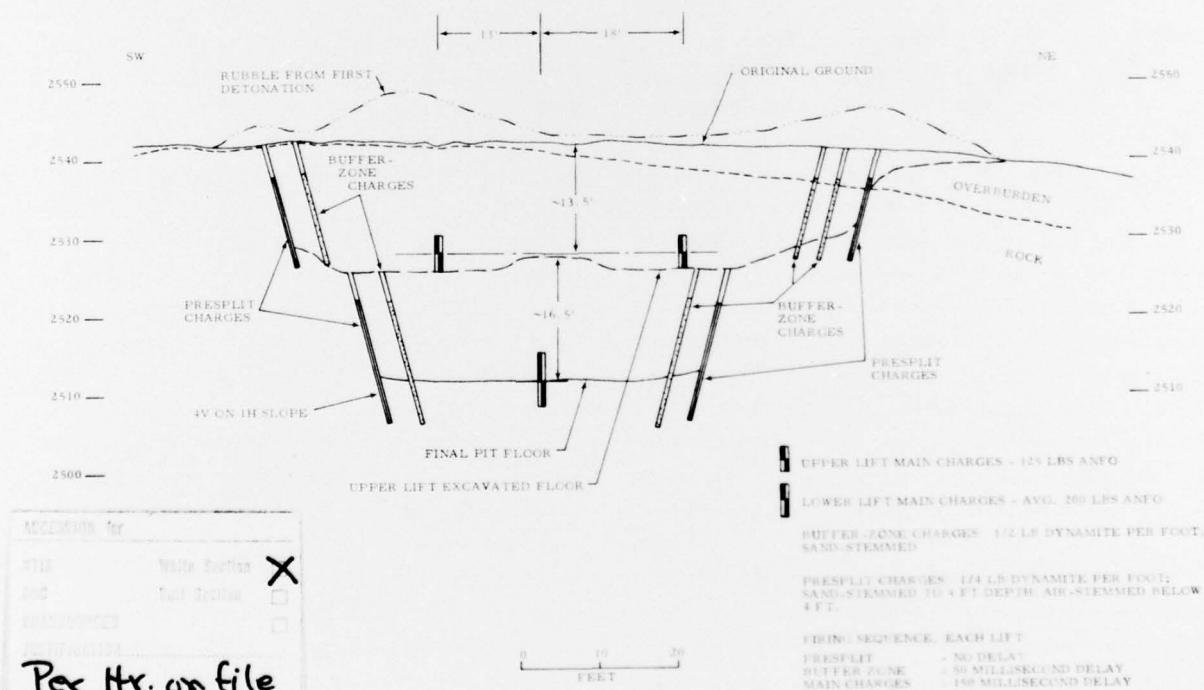


Fig. 2. Cross-sectional view, ML experiment



Fig. 3. Completed cut. View toward the south

Spacings in the second lift were adjusted on the basis of first-lift results. Varying the geometry of the buffer zone seemed to have little effect; therefore, single-line buffer zones were used in the second lift.

Each lift was blasted in a single explosive event. In each case the presplit charges were fired first; the buffer-zone charges were detonated 50 msec later by the use of delay blasting caps; the main ANFO charges were detonated 150 msec after the presplit charges. Fig. 4 shows the firing of the first lift: the presplit and buffer-zone



Fig. 4. First-lift detonation, showing presplit and buffer zones already detonated with mounding charges to follow shortly

charges have detonated, but the main charges have not yet fired.

The rock fragmented well because of the extensive natural fracture system. The broken rock was excavated with two bulldozers: a D-8 and a D-9, the latter with a single-tooth ripper. The ripper tooth succeeded in dislodging rock near the bottom of the first lift which, though broken, remained keyed in place. In addition, a

track-mounted front-end loader with a toothed rock bucket was used for final clean-up.

Fig. 5 shows the ML experiment after excavation of the upper lift. The well-formed presplit surface lies along the west side of the cut. Charge emplacement holes for the main charges of the second lift are in the foreground, marked by plywood hole covers. The second-lift blast filled much of the first-lift trough with rock rubble (fig. 6).



Fig. 5. First lift fully excavated. Plywood squares cover second-lift charge emplacement holes



Fig. 6. Rubble from second-lift blast fills first-lift trough. Presplit surface at left

Several technical programs were associated with the LOST CREEK detonations. Subsurface particle-velocity measurements were made during most of the experiments. Although the two velocity gages monitored during the ML experiment did not provide meaningful data, useful data were acquired from several other test blasts. An NX-size diamond-drill hole was drilled 4 ft behind the presplit wall of the upper lift at the ML experiment. Core from this hole was subjected to laboratory strength testing, and the borehole walls were photographed before and after the first-lift detonation; very little new fracturing as a result of the blast could be detected. The same hole was subjected to water pressure testing before and after the blast. The upper 17 ft of the hole was markedly leakier after the

blast than before, indicating certain blast-induced fracturing that could not be detected from borehole photography. Measurements were made of seismic shock at distances ranging from 1600 to 8100 ft and of airblast overpressures to ranges of about 1000 ft.

The experimental blasts and excavation proved that a structural cut such as a spillway can be produced in suitable rock using mounding charges augmented by controlled blasting panels. The economic advantages of the technique in comparison with conventional blasting practice will probably be dependent on the scope of the project.

A potential problem in the use of mounding charges is the existence of mounds of unbroken rock along the floor of a lift, particularly at the edges. This problem was encountered in the ML excavation, even though the bottoms of presplit and buffer-zone holes were extra-loaded in an attempt to overcome it. It may be necessary to incorporate secondary blasting into plans for a mounding excavation; however, the small drills required for this would be available because of the presplitting operations.

The fragmentation produced by the mounding charges in the LOST CREEK test program was studied by comparing preblast fracture spacings in emplacement boreholes with rubble block sizes. It was apparent that the rock fragmentation was controlled by the extensive natural fracture pattern. The few large slabs of rock remaining after the blast fell apart when moved by the bulldozers, but a less fractured rock may be more troublesome. The large equipment necessary to handle large fragments could be economically justified on a large project.

The ML experiment clearly demonstrated the technical feasibility of producing a structural excavation with mounding charges and controlled blasting.

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